DOSIMETRIC EVALUATION IN CARCINOMA LUNG BY INTRALUMINAL BRACHYTHERAPY AND CORRELATION IN PHANTOM MODEL

A

SYNOPSIS

SUBMITTED TO

SWAMI RAMA HIMALAYAN UNIVERSITY

DEHRADUN (UTTARAKHAND)

in fulfillment for award of the degree of

DOCTOR OF PHILOSOPHY

IN

MEDICAL PHYSICS

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DECLARATION

I hereby declare that the synopsis entitled "**Dosimetric evaluation in carcinoma lung by intraluminal brachytherapy and correlation in phantom model**" submitted to the Swami Rama Himalayan University is my original work and it has not been submitted for any other degree or diploma at any other university or institute.

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Background

Worldwide one of the most common cancers is Lung (2.09 million cases) and most common cause of death is by Lung cancers (1.76 million deaths). In India each year 63,000 (approximately) new lung carcinoma cases are reported (1). The main risk factors worldwide for lung carcinoma are using Tobacco, alcohol, unhealthy diet, and physical inactivity. The cancer burden can be reduced by avoiding the risk-factors and by executing the strategies which exist for prevention. If cancer diagnosed early and treated effectively, many cancers have cure rate with high chance.

The treatment of cancer depends upon type of cancer and stage of the disease as each subtype needs specific treatment regimen which includes surgery, radiation therapy and chemotherapy. The primary goal is to cure carcinoma and improve quality of life of cancer patient which can be attained by using optimal modality of treatment as single modality or in combination. (2)

Radiation Therapy is one of the principal modality used for the treatment of cancer as a single modality or in combination with other available modalities of treatment. Radiation therapy is delivered by two methods, external beam radiation therapy (EBRT) and brachytherapy (BT). The EBRT is treatment of tumor from some distance and brachytherapy is precise placement of the small encapsulated radioactive source directly inside or in close proximity of the tumor. Advantage of using brachytherapy is to deliver maximum localized dose to the tumor and spare healthy tissues which is the main objective of radiation therapy [3, 4].

In lung cancer, radiation therapy is used in small cell carcinoma with curative intent in combination of chemotherapy. In non-small cell carcinoma of lung surgery is the main type of treatment whereas radiation therapy is used as adjuvant or for palliation.

Radiation Therapy used in lung carcinoma is manly by EBRT however there are indication where radiation therapy is used as brachytherapy.

The “American Brachytherapy Society” (ABS) issued guidelines for brachytherapy (5) in lung carcinoma. ABS recommends that the patients with hemoptysis and post obstructive pneumonitis can be considered for palliative Endobronchial (EB) Brachytherapy. The tumors involved the lumen which compresses the bronchus/ trachea and leads to cough, breath shortness with hemoptysis. EB brachytherapy generally give fast palliation of blockage than external beam radiation therapy.

The ABS recommends that EB brachytherapy is performed via transnasal technique with the help of flexible fiber optic bronchoscope under conscious sedation administered by well-trained person. A guide wire is used to visualize the catheter under fluoroscopy because through bronchoscopy endobronchial

lesion is visualized but not by fluoroscopy. Markings on catheter define its location relative to the tumor and helps in treatment planning. The catheter insertion is completed with the help of bronchoscopy. The ABS suggests that 7.5Gy/ fraction per week for 3 weeks, 10Gy/ fraction per week for two weeks or 6Gy/fraction per week for four weeks when HDR brachytherapy is used for palliation.

The dose prescription point in endobronchial HDR brachytherapy can be selected by two ways, one is at 1.0cm from the catheter center and other one is at various distances around the catheter center which depends upon the trachea or bronchial diameter at that level. To treat the tumor adequately a margin of 1cm to 2cm is recommended at each end of the catheter. The optimized dose distribution is completed in the treatment planning system (TPS) dedicated to HDR brachytherapy.

The accurate and reliable quantification of brachytherapy dose distributions is of vital importance in clinical treatment planning. The distribution of dose around the radioactive source used in brachytherapy is classified by energy spectrum with sharp dose gradients varying rapidly about the source by means of depth in water. The doses around brachytherapy sources can be determined by experimental and Monte Carlo methods. Accurately placement of the detector is important for radiation dose measurement and measured signal is proportional to the relative/ absolute dose in the absence of detector in the medium. The detectors are used in this application include small TLDs dosimeters, Gafchromic film, ionization chamber.

As far as the suitability of dosimeter is concerned, TLD has already been established as a detector offering best compromise between small size, sensitivity, flat energy response and ease of accurate positioning. The “American Association of Physicists in Medicine” (AAPM) also recommends TLDs LiF based to be used for dose verification measurements for brachytherapy applications [6]. However, the method based on TLD is cumbersome and related with volume averaging, positioning errors and self-attenuation factors. The ionization chamber is capable of real time dosimetry does not fulfill the requirement of resolution because of finite physical dimension of the detector. In addition, positioning of ion chamber in the order of the brachytherapy source is also labour intensive and time consuming. In recent times radiochromic film such as Gaf-chromic EBT series films are in use for experimental dosimetry in brachytherapy [7, 8, 9]. EBT films provide nonlinear dose response. Gafchromic EBT3 film is the most recent version of EBT series films. EBT3 film exhibits high resolution which makes it appropriate for measuring rapidly falling doses around brachytherapy sources. The film is nearly tissue equivalent and possesses low energy dependency within the range of calibration. In addition, dosimetry

with Gafchromic film is a user friendly and cost effective method which is convenient to be used even in a busy clinical set-up.

An important part of the brachytherapy treatment planning is the calculation of absorbed dose distribution in a patient body. In an attempt to minimize the large variation of dosimetric information determined by various investigators, the AAPM Task Group 43 (TG 43/TG43U1) [10] has recommended a formalism for determining the distribution of dose rate in water medium about a single sealed source used in brachytherapy. The algorithm of dose calculation in the most brachytherapy treatment planning systems (TPS) is based on this formalism which assumes a homogeneous water equivalent medium around the source. This difference between the planned and the actual condition include the effects of patient heterogeneities, applicators attenuation and the altered scatter conditions etc. Inaccurate treatment causes late complications and significantly reduces quality of life. Thus it is important to quantify the difference among TPS calculated and actual dose delivered. [11].

There is very less data available on the dosimetry of carcinoma lung brachytherapy. So aim of the study is to perform a volumetric and dosimetric analysis in carcinoma lung for palliative treatment and verify the doses to OARs in TPS planned and actually delivered doses in a phantom designed for site specific with the help of Gaf-chromic film dosimeters. This study will help in accurate treatment delivery and improvement in the quality of life of the patient.

Review of Literature

It is evident that treatment outcome entirely depends on the accuracy with which tumor has been delineated, precision of treatment planning using radiation dosimetry. The advance imaging modality such as multi-slice CT scanner, functional MRI and PET-CT provided newer approach in delineating target volume and OARs for accurate dose delivery.

The use of endobronchial brachytherapy increases after the development of high activity Iridium-192 source in remote afterloading HDR machine along with use of bronchoscope (fiberoptic).

S. Sennan et al describe the toxicity, like fatal haemoptysis and necrosis of bronchial wall, of endobronchial brachytherapy (EB) and linked with total dose, size of the fraction and volume covered by the 100% isodose. They treated sixteen patients with palliative EB HDR BT planned on CT data. A 3D optimized treatment plan was generated on the CT data and analyzed through dose volume histograms. CT-assisted EB is feasible and reduces the toxicity of fractionated EB by accurate dose prescription to the mucosa in the curative treatment. (12)

Prof. Janusz Skowronek et al. did a study and explained that the most patients diagnosed advanced disease of lung carcinoma. Those patients were having short life and treated by palliative intent. Patients may have the cough, hemoptysis, dyspnea and atelectasis or obstruction pneumonia due to the disease. Brachytherapy is most effective method to clear the endobronchial obstruction in carcinoma of bronchus. This may increase the quality of life of the patient. In early endobronchial disease was treated by brachytherapy with curative intent. Brachytherapy is a treatment of choice for some cases which is easy to perform on outpatient basis, inexpensive. In this study they have presented complications, different techniques and clinical indications. (13)

Meenu Gupta et al. did a study to find out the safety and effectiveness of HDREB in palliative treatment to advanced endobronchial disease. Fifteen patient of advanced disease were treated as per the protocol. HDREB brachytherapy treatment was done with Ir-192 HDR source in remote afterloading machine. Dose delivered 7Gy/fraction per week to the lesion in the trachea and in bronchi. The results showed that there was 84.53% performance enhancement with migration of patient. The symptom response was 93.3% hemoptysis, 87% post obstructive pneumonia, dyspnea improvement was observed in 73.3%. There was 67% Radiological response and 73.3% endoscopic partial response. Radiation bronchitis was temporary seen in three patients. (14)

Nikoofar A et al. did study to determine the dose to OAR's (parotids, eyes, thyroid gland, trachea, sub-mandibular, spinal and manubrium of sternum in an anthropomorphic phantom in HDR brachytherapy.

Radiation doses to OAR's were measured in the anthropomorphic body phantom by the use of TLDs. A target volume (TV) of around 23 cm3 was taken in upper thoracic cavity and phantom was scanned in CT. After the planning, phantom was exposed to the HDR remote after-loading machine. The doses (in cGy) were measured with TLDs calibrated for the dose range. In the areas greater than 16 cm from target measured dose was ranged from 1.65cGy to 5.5cGy and in nearer areas lesser than 16 cm the dose was found high as 113cGy. So the study showed in the nearer areas, the surface doses and depth doses were significantly changed because of high dose gradient and difference among plan and measured doses because of the tissue inhomogeneity. (15)

Hiroyuki Okamoto et al did study to evaluate the dosimetric influence of air passage on carcinoma of bronchus brachytherapy by TPS calculated and Monte Carlo simulation method. They analyzed patient CT data information that had gone for ILRT HDR brachytherapy to check the air passage geometry. They developed a system of measurement which is capable to measure exterior dose with air cavity or without air cavity around catheter by ionization chamber. They modeled 5 (five) cavities of air with radii of 0.3cm, 0.5cm, 0.75cm, 1.25cm and 1.5cm by cylindrical tubes around the catheter. The dosimetric effect of the air cavity was evaluated by the GEANT4 Monte Carlo code method. The dose measured in water and calculated in GEANT4 were compared which showed maximum overdose of 5% to 8% near the air cavity surface in maximum radii 1.5cm. On the other hand, they showed a minimum overdose in the region 3cm to 5cm from surface of the cavity is ~1% for 0.3cm radii. The air passage distance, size and length of treatment effects the dosimetry Overdose of 3-5% for a 0.75cm mean radii was found for the bronchus carcinoma ILRT brachytherapy depend upon the dose calculation in TPS and water. This research work showed the requirement for development in accuracy of dose calculation in ILRT for carcinoma bronchus. (16)

Sneha Dhillon et al. used HDR-EB brachytherapy for the treatment of endobronchial carcinoma to assess the short-term clinical, acute toxicities and endoscopic response. They included thirty patients of advanced carcinoma of endobronchial region. The dose prescription was done in HDR-EB brachytherapy at 1 cm distance from center of the source axis. They treated patients for 3 weeks with gap of one week with dose of 7Gy/ fraction. The data was taken before the treatment and after one month of treatment completion. The severity of symptoms and degree of obstruction were graded by Speiser's scoring criteria. They found 88% response in cough, 75% response in dyspnea and 96% response in hemoptysis with <0.05 P-value which is significant. The degree of obstruction was found by the endoscopic response in 84% of patients. Acute toxicities were seen in 32% of patients of radiation bronchitis. Resolution in

Obstructive pneumonia was seen in 94% of patients. Esophagitis was seen in 8% of patients and during treatment Bronchospasm was seen in one patient. The conclusion was that the HDR brachytherapy is safe, convenient and highly effective for endobronchial obstruction with response by endoscopy in most of the cases. Therefore, HDR-EB BT is a favorable palliation treatment of patients suffering of symptoms of endobronchial obstruction with tolerable complications. (17)

Barlanka Ravikumar et al did study to find the correction of tissue inhomogeneity for HDR Ir-192 source in HDR brachytherapy. They used 0.015 cc ion chamber to measure and quantify the inhomogeneity's impact caused by different tissues. Ir-192 HDR brachytherapy source and wax phantom were used for the measurement of heterogeneities. The dose reduction caused by tissue inhomogenities was measured for different distances as the dose with inhomogeneity divided by the dose with homogeneous medium. The result was different as tissue attenuate differently. The attenuation value showed by tissue was maximum with bone and minimum for lung. The result showed that at short distances inhomogeneity was higher than the larger distances. (18)

Akbar Adelnia and Daryoush Fatehi et al did a theoretical analysis to find the effect of dimensions of phantom and heterogeneities of tissue on dose distribution in interstitial brachytherapy. They used Gaf-chromic film for dosimetric measurement and Monte Carlo simulation for Iridium-192 HDR source. The result of their study was 8.2% dose underestimated for lung and 9% overestimated for bone in the TPS system. The thickness and distance from the source affects the above value. Therefore, TPSs cannot include the effect of tissue heterogeneity of on dose distribution in brachytherapy. (19)

Objectives

Primary Objective:

1. To compare the organ at risk doses, calculated in Treatment Planning System and measured at different locations in a tissue equivalent phantom designed for thoracic site.

Secondary Objective:

1. Dosimetric analysis of organ at risk and target volume doses in each Endobronchial Intraluminal brachytherapy treatment session in the treatment planning system.
2. To evaluate the variation in target volume after each session of Endobronchial Intraluminal brachytherapy in the treatment planning system.
3. To evaluate and compare the target volume and organ at risk doses in external beam radiation therapy plan and endobronchial high dose rate brachytherapy treatment plan in treatment planning system for carcinoma of lung.

Hypothesis

Hypothesis of this study are as follows:

1. If the doses to organs at risk differ significantly from planned doses in the treatment planning system to the actual measured doses in the phantom for the carcinoma lung then the quantification of these affecting factors will be required.

2. If the volumetric and dosimetric analysis results for organs at risk doses and optimized tumor coverage are found significant to the patient then endobronchial intraluminal brachytherapy will be adopted for palliative treatment in carcinoma lung to minimize radiation treatment related complications.

3. If there will be major difference in absorbed doses evaluated for the organs at risk with adequate target volume coverage in external beam radiation therapy (EBRT) and endobronchial high dose rate brachytherapy (EBHDR BT) for palliative treatment plan then the endobronchial high dose rate brachytherapy shall be preferred for palliative treatment in carcinoma of lung.

Methodology

The study will be conducted in the Department of Radiation Oncology, Cancer Research Institute, Swami Rama Himalayan University (SRHU), Swami Ram Nagar, Dehradun over a period of three year.

STUDY DESIGN:

Type of study: Prospective and observational.

Inclusion Criteria: Patients of carcinoma of lung will be taken for the study with the endobronchial tumor in the primary and secondary bronchus of carcinoma lung.

Exclusion Criteria: Patients of carcinoma of lung will not be taken for the study with the tumor in the plural and peripheral part of the lung other than primary and secondary bronchus.

STEPS IN METHODS:

- A written informed consent and ethical clearance certificate will be taken from Institutional Ethics Committee.
- The tumor extension will be measured by bronchoscopy and contrast enhanced computed tomography (CECT) chest.
- A flexible Lumencare catheter (6 French) will be inserted into the lumen and positioned the tip of catheter at least 2 cm beyond the visible tumor.
- The exact treatment length will depend on the involvement of bronchial wall, commonly 5 to 7 cm length irradiated.
- The CT simulation will be performed for each session of every patient after the insertion of Lumencare catheter into the patient with x-ray marker placed in catheter.
- Length of the implanted catheter will be measured by the source position simulator tool.
- Acquired 3D CT data set of the patient will be send to the Treatment Planning System for further planning.
- The OAR's and target volume will be delineated for the accurate assessment of doses to OAR's and target volume in each brachytherapy treatment session.

- Treatment plan will be generated and dose prescription will be done at 1.0cm from the center of the catheter placed in the lumen.
- Doses to OAR's and target volume will be noted from the dose volume histogram tool and detailed dose volume table in the treatment planning system.
- After achieving the optimized dose distribution, the final plan will be sent to the treatment unit for the treatment execution.
- Volume and dimensions of the target and the organ at risk with external body contour will be measured in the treatment planning system for each patient.
- These measurements will be helpful in designing a phantom of thoracic site for the simulation of a carcinoma of lung patient to tissue equivalent phantom.
- The phantom will be constructed having almost same density material to the structures in thoracic region of the patient body.
- The phantom will be scanned in CT simulator and acquired data set will be sent to TPS for further planning. An optimized plan will be generated in the TPS.
- To execute this plan in the HDR unit Gafchromic films will be placed at different positions in the phantom to measure the actual doses.
- Then the measured doses will be analyzed and compared with the TPS plan doses at the same position in phantom. DVH tool will be used to assess the data for the analysis.
- The analyzed data will help us to find out the factors which are affecting the dose distribution in the treatment of carcinoma lung brachytherapy.
- External beam radiation therapy (EBRT) plan will be generated for the same patient data set and the dosimetric analysis will be done in TPS for the same prescribed dose.
- The equivalent doses will be calculated for the EBRT and brachytherapy treatment modality for comparison.
- Both EBRT and EBHDR brachytherapy plans will be compared to analyze the OAR's doses along with adequate target volume coverage.
- DVH analysis will be performed to assess the doses to OARs for the EBHDR BT and EBRT plan.

MATERIALS REQUIRED:

- Lumencare Azure 6Fx150cm flexible tube with closed tip end
- CT Simulator machine (Somatom Emotion Duo Siemens make)
- Source position simulator along with x-ray marker with adaptor
- Treatment Planning System
- HDR Brachytherapy unit (microSelectron HDR V3, 30 Channel)
- Tissue equivalent material for phantom design,
- Gafchromic films,
- IBM SPSS software 22.0 version for statistical analysis.

STATISTICAL ANALYSIS:

The data will be gathered as well as entered in 2010 MS excel sheet. Different statistical analysis will be performed by using SPSS software version 22. The one –sample Kolmogorov-Smirnov Test will be employed to determine whether the data sets differed from a normal distribution or not. Normally distributed data will be analyzed using parametric tests and non-normally distributed data will be analyzed using non-parametric tests. Descriptive statistics will be calculated for quantitative variables. Frequency along with percentages will be calculated for qualitative and categorical variables. Graphical representation of the variable will be shown to understand the result clearly and7 the categorical data will be analyzed using Chi-Square test.

If $p<0.05$, then hypothesis will be said to be statistically significant and if $p>0.05$, then hypothesis will be said to be statistically insignificant.

Sample size is calculated by the following formula:

$$n = \{(Z_{\alpha/2})^2 Pq\}/ l^2$$

Where, α= is 5% level of significance

P= 50% {Unknown exposure}

l = take 25% relative precision

The sample size is calculated by the above formula and it is n= 61. Therefore 61 patients of carcinoma of lung will be included in this study and analyzed thereafter.

Expected Outcome

This study will be performed to help in the treatment planning and accurate radiation dose delivery to the site and organs at risk which may be helpful in improving the quality of life of patient and minimizing the complications to the patient after treatment. The doses to the organ at risk in intraluminal brachytherapy of carcinoma lung is the limitation so this study will also validate the organ at risk (OAR) doses by comparing treatment planning system (TPS) planned doses to actually received doses to OAR's by dosimetry in phantom model for the thoracic site. The study will help to identify the factors affecting the brachytherapy dose distribution to organ at risk with aim to reduce complications resulting from inaccuracy in calculation of the doses of radiation by available methods of dosimetry.

References

1. Epidemiology of lung cancer in India: Focus on the differences between non-smokers and smokers: A single-centre experience; Noronha V, Dikshit R1, Raut N2, Joshi A, Pramesh CS3, George K3, Agarwal JP4, Munshi A4, Prabhash K. Indian Journal of Cancer | January-March 2012 | Volume 49 | Issue 1
2. https://www.who.int/
3. Barlanka Ravi Kumar et al.: Determination of the Tissue Inhomogeneity Correction in High Dose Rate Brachytherapy for Iridium-192 Source. J Med Phys. 2012 Jan-Mar; 37(1): 27–31.
4. R. M. Chandola, et al.: Effect of inhomogeneities and source position on dose distribution of Nucletron high dose rate Ir-192 brachytherapy source by Monte Carlo simulation. J Cancer Res Ther - January-March 2010 - Volume 6 - Issue 1
5. Subir Nag, Jason F. Kelly, John L. Horton, Ritsuko Komaki, and Dattatreyudu Nori, et al.: Brachytherapy for Carcinoma of the Lung Review Article [1] | March 01, 2001. Published on Physicians practice.
6. Update of AAPM Task Group No. 43 Report: A revised AAPM protocol for brachytherapy dose calculations
7. Satish C. Uniyal et al.: Radiochromic film dosimetry of rectal inhomogeneity and applicator attenuation in high dose rate brachytherapy of uterine cervix. Journal of applied clinical medical physics, volume 13, number 1, 2012
8. Matthew Williams et al.: Radiochromic Film Dosimetry and its Applications in Radiotherapy. 2011
9. S.C. Uniyal et al.: A dosimetry method in the transverse plane of HDR Ir-192 brachytherapy source using Gafchromic EBT2 film. Physica Medica European Journal of Medical Physics. **April 2012** Volume 28, Issue 2, Pages 129–133.
10. Rivard et al.: Report of the AAPM Radiation Therapy Committee Task Group 43 (TG 43/TG43U1) report, Med. Phys. 31(3), March 2004.
11. Antony Palmer, David Bradley, Andrew Nisbet et al.: Physics-Aspects Of Dose Accuracy In High Dose Rate (HDR) Brachytherapy: Source Dosimetry, Treatment Planning, Equipment Performance And In Vivo Verification Techniques. Journal of Contemporary Brachytherapy. 2012 Jun; 4(2): 81–91

12. A CT-assisted method of dosimetry in brachytherapy of lung cancer; Suresh Senana,*, Frank J. Lagerwaarda, Connie de Pana, Dick Sipkemaa, Sjaak A. Burgersb, Lars H.P. Murrera, on behalf of the Rotterdam Oncological Thoracic Study Group, Elsevier Radiotherapy and Oncology 55 (2000) 75-80.
13. Prof. Janusz Skowronek, MD, PhD et al.: Brachytherapy in the treatment of lung cancer – a valuable solution. J Contemp Brachytherapy 2015; 7, 4: 297-311
14. Meenu Gupta, Saurabh Bansal, Girish Sindhwani, Ravi Kant, Vipul Nautiyal et al. High-Dose Rate Endobronchial brachytherapy (HDREB) for palliation of lung cancer: An Observational study. INDIAN JOURNAL OF APPLIED RESEARCH, Volume: 6 | Issue : 7 | July 2016
15. High-Dose-Rate 192Ir Brachytherapy Dose Verification: A Phantom Study; Alireza Nikoofar 1; Zohreh Hoseinpour 2; Seied Rabi Mahdavi 3; Hadi Hasanzadeh 4,*; Mostafa Rezaei Tavirani 5, Iran J Cancer Preven. 2015 May; 8(3):e2330.
16. Dosimetric impact of an air passage on intraluminal brachytherapy for bronchus cancer Hiroyuki Okamoto*, Akihisa Wakita, Satoshi Nakamura, Shie Nishioka, Ako Aikawa, Toru Kato, Yoshihisa Abe, Kazuma Kobayashi, Koji Inaba, Naoya Murakami and Jun Itami, Journal of Radiation Research, Vol. 57, No. 6, 2016, pp. 637–645
17. Clinical and endoscopic response to high dose rate endobronchial brachytherapy in malignant lung tumors: A single centre experience. Sneha Dhillon, Saurabh Bansal, Girish Sindhwani, Meenu Gupta, Vipul Nautiyal, Sunil Saini, Mushtaq Ahmad; South Asian J Cancer 2018;7:267-9.
18. Determination of the tissue inhomogeneity correction in high dose rate Brachytherapy for Iridium-192 source; Barlanka Ravikumar, S. Lakshminarayana1, Department of Radiotherapy, Government General Hospital, Kakinada, 1Department of Nuclear Physics, Andhra University, Visakhapatnam, Andhra Pradesh, India Journal of Medical Physics, Vol. 37, No. 1, 27-31
19. Estimation and Evaluation of Tissue Inhomogeneity Effect on Dose Distribution for High Dose Rate Iridium 192 Source Using Monte Carlo Simulation and Film Dosimetery; Akbar Adelnia and Daryoush Fatehi; Department of Medical Physics, Faculty of Medicine, Tarbiat Modares University, Tehran, Iran; Adelnia and Fatehi, J Nucl Med Radiat Ther 2016, 7:6, Volume 7 • Issue 6 • 1000312.

STUDY PERFORMA- I

Table 1: Doses to Organ at risk and target volume calculated in TPS and measured in phantom

Organ	Absorbed Dose, cGy		Mean Distance From Target, cm	Variation
	TPS Calculated	Phantom Measured		
Thyroid				
Surface				
Depth				
Trachea				
Surface				
Depth				
Esophagus				
Surface				
Depth				
Heart				
Surface				
Depth				
Coronary Artery				
Surface				
Arc of Aorta				
Surface				
Pulmonary Trunk				
Surface				
Ipsi-lateral Lung (Lung-PTV)				
Surface				
Depth				
Contra-lateral Lung				
Surface				
Depth				
Spinal cord				
Surface				
Depth				
Liver				
Surface				
Depth				
Kidney				
Surface				
Rib				
Surface				
CTV				
PTV				

STUDY PERFORMA- II

Patient UHID:		**Age/ Sex:**	
Diagnosis:		**Contact Number:**	
Site (Detail):		**Other:**	

Table 2: Volumetric and dosimetric analysis in Intraluminal brachytherapy of carcinoma lung

Organ	Absorbed Dose, cGy				Mean Distance From Target, cm	
	1st Session	2nd Session	3rd Session	Total		
Esophagus						
Dmean						
Dmax						
D5%						
D15%						
D107%						
Ipsi-lateral Lung						
Dmean						
D5%						
D10%						
D20%						
D37%						
V107%						
Contra-lateral Lung						
Dmean						
D5%						
D10%						
D20%						
D37%						
V107%						
Heart						
Dmean						
Dmax						
D5%						
D20%						
D10%						
V107%						
Arc of Aorta						
Dmean						
Dmax						
Spinal cord						
Dmax						
Liver						
Dmean						

Dmax						
D5%						
D10%						
D20%						
Kidney						
Dmean						
Dmax						
D5%						
D10%						
Thyroid						
Dmax						
Trachea						
Dmax						
Coronary Artery						
Dmax						
Ribs						
Dmax						
CTV						
D5%						
D95%						
D107%						
V95%						
Volume (%)						
Volume (cc)						
PTV						
D5%						
D95%						
D107%						
V95%						
Volume (%)						
Volume (cc)						
Conformity Index						
Homogeneity Index						

STUDY PERFORMA- III

Table 3: Organ at risk and target volume dimension measurement for designing a Thorax body phantom

Organ	Measurement				
	Diameter	**Height/Length**	**Volume**	**Mean Distance From Target, cm**	
Thoracic cavity					
Skin + muscle thickness					
Anterior					
Posterior					
Right Lateral					
Left Lateral					
Esophagus					
Lower					
Middle					
Upper					
Ipsi-lateral Lung (Lung-PTV)					
Lower					
Middle					
Upper					
Contra lateral Lung					
Lower					
Middle					
Upper					
Heart					
Lower					
Middle					
Upper					
Coronary Artery					
Arc of Aorta					
Ribs					
1-12					
Intercostals space					
Sternum					
Lower					
Middle					
Upper					
Vertebrae					
D1-D12					

Spinal cord					
Lower					
Middle					
Upper					
Diaphragm					
Liver					
Kidney					
Thyroid					
Trachea					
Lower					
Middle					
Upper					
Bronchus					
Primary					
Secondary					
Tertiary					
CTV					
PTV					

STUDY PERFORMA- IV

Table 4: Dosimetric comparison of EBRT and EB HDR Brachytherapy plans for OARs & tumor

Organ	Absorbed Dose, cGy		Mean Distance From Target, cm	P-Value
	EB HDR BT Plan	EBRT Plan		
Esophagus				
Dmean				
Dmax				
D5%				
D15%				
D107%				
Ipsi-lateral Lung				
Dmean				
D5%				
D10%				
D20%				
D37%				
V107%				
Contra-lateral Lung				
Dmean				
D5%				
D10%				
D20%				
D37%				
V107%				
Heart				
Dmean				
Dmax				
D5%				
D20%				
D10%				
V107%				
Arc of Aorta				
Dmean				
Dmax				
Spinal cord				
Dmax				
Liver				
Dmean				
Dmax				
D5%				
D10%				
D20%				

Kidney				
Dmean				
Dmax				
D5%				
D10%				
Thyroid				
Dmax				
Trachea				
Dmax				
Coronary Artery				
Dmax				
Ribs				
Dmax				
CTV				
D5%				
D95%				
D107%				
V95%				
Volume (%)				
Volume (cc)				
PTV				
D5%				
D95%				
D107%				
V95%				
Volume (%)				
Volume (cc)				
Conformity Index				
Homogeneity Index				

Homogeneity Index (HI) = D5%/D95%

Where, D5% is dose received by the 5% volume of PTV
D95% is dose received by the 95% volume of PTV

Smaller HI implies better treatment plan.

Conformity Index (CI) = Volume covered by 95% Isodose/ Total target Volume